ANALYSIS OF WAYS REDUCING DRILLING WASTE IN OIL AND GAS PRODUCTION INFLUENCING ON NATURAL ENVIRONMENT

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The influence of drilling waste, while setting in the well, during oil production and exploitation of oil and gas wells is considered. When evaluating the ecological hazard of the well drilling process, the properties of drilling mud, drilling sludge and drilling wastewater are analyzed. It is outlined that the chemical composition of drilling waste depends on the properties of the drilling mud and the mineral composition of the drilling sludge. The mineralogical composition of the drilling sludge is determined by the lithologic composition of rocks that are drilled through; it may change depending on the well depth. The factors of influence on the natural environment during drilling and exploitation of the deposit are defined. The modern technologies of oil drilling sludge decomposition into components are analyzed. The analysis of modern drilling waste recycling method results can be used to increase the ecological safety of oil-producing areas. The results of drilling waste composition research can be used for further recycling and rational usage.

1. Analysis of the ecological state of oil and gas production regions

1.1 General characteristics of oil and gas production in Ukraine

The oil and gas industry in Ukraine has a negative impact on the hydro-, atmospheric, lito- and biosphere [1]. Drilling wells and producing hydrocarbons are environmentally hazardous processes

[2]. Oil and natural gas reserves in Ukraine are concentrated in the following geographic and geological regions: the Donets'k-Dnipro basin, the Precarpathian basin, the Black Sea-Crimean region [3].

The most progressive mineral-energy resource is hydrocarbon raw materials (oil, gas and condensate). Nowadays, Ukraine has 323 hydrocarbon deposits.

Most of them, i.e. 191 deposits, are situated in the Eastern region, 96 ones are in the West, and 36 ones are in the South. The average annual output is 4 million tons of condensed oil and 18 billion m^3 of gas, which is equal to 10 and 20 % respectively, considering the amount of these raw materials consumed by the country per year [4].

The depth of oil and gas wells that are drilled in Ukraine is on average from 2500 meters to 6000 meters. Technologically, the drilling process includes three main stages:

- mechanical destruction of rocks in the well;
- removal of rocks out by means of a drilling mud (DM), which is prepared outside before being fed by pumps into the well under pressure;
- mounting well walls by casing pipes (technical or operational columns).

The process of drilling is accompanied by occurance of drilling waste (DW): drilling sludge (DS), worked out drilling mud (WDM), drilling wastewater (DWW) [5].

Characteristics of the drilling sludge, which occurs during the oil and gas well drilling, testifies about impurities in it (Table 1).

Table 1

Comparative characteristics of the drilling sludge, coming out at oil production enterprises

Indicators of research/batch, type of waste	DS1	DS2
Oil products, g/kg	0,3	0,4
Humidity, %	53	47
Dry residue, g/kg	63,8	56,6
pH	7,2-7,6	10,8-11,0
Cl, g/kg	18,1	7,7
Ca^+, Mg^+, g-equal/l	0,025	0,07

As the well is deepened onto the following face (the location of the mechanical device (the drill) that destroys the rock), drilled rock, coming out along with a circulating drilling mud (flushing liquid), is formed [1]. Outside, drilling waste passes the cleaning system and then it is delivered into the sludge barns, where it is sorted out into drilling sludge (DS), worked out drilling mud (WDM) and drilling wastewater (DWW).

Well drilling is carried out mainly in sedimentary deposits, where clay rocks are dominant. Drilled clayey particles, risen outside, are mixed with the drilling mud filtrate and swell.

The mineralogical composition of the drilling mud is determined by the lithologic composition of rocks that are drilled. It may change according to well deepening. The chemical composition of the drilling sludge depends on its mineral composition and the properties of the drilling mud [6].

1.2 Pollution of the oil and gas production regions in Ukraine

If oil or its products fall into reservoirs, they intoxicate hydrobionts and reduce the concentration of dissolved oxygen. For instance, with insufficient oxygen content various defects in fish embryo structure may occur. When the oxygen level in water decreases, the fish embryos can not fill in their swimming bladders with air, swim up and start eating, and as a result die. Increasing the content of biogenic elements leads to the eutrophication of the reservoir, the transparency of water drops sharply, sunlight almost does not penetrate into water and there is no process of photosynthesis [7].

The problem of possible contamination of drinking water occurs in places bordering drinking water intakes. This problem is urgent while drilling deep oil and gas wells, which cause changes in ionic and organic composition of water. Conditionally three stages of man-made metamorphism of groundwater can be distinguished:

- On the first stage of deep well drilling, there is a slight contamination of groundwater with sulfate ion, organic matter and chlorine ions.

- On the second stage, namely after the opening a deep of the oil and gas well productive horizon in ground waters, the content of magnesium ions increases approximately twice, chlorine and sulfate ions increase almost 1.5 times, oil products increase approximately 4 times, and phenols increase 1.3 times.

- On the third stage, after the completion of deep well drilling, processes of landscape self-cleaning come to pass. Over the next two years, as the research shows, the number of certain contaminants decreased by about 2 times [8].

2 Impact of drilling itself and drilling waste on the natural environment

The main types of oil and gas well drilling process waste are as following:

- DS (drilling sludge), water suspention, the solid part of which contains drilled rock products of the face and well walls, a drilling rig and casing pipes abrasion products, clay minerals (when flushed with an argillaceous solution) [9];
- DWW (drilling wastewater), water formed while flushing the drilling rig, drilling equipment and tools, after cleaning the vibration grid and cooling pumps; it contains residues of worked out drilling mud, chemical reagents and oil. DWW is a multicomponent system; the main components of DWW contamination are suspended organic matter and oil products. In appearance, drilling wastewater is a brown or dark brown mixture, which is practically opaque with a slight odor of oil products [10];
- WDM (worked out drilling mud) is a solution that has been excluded from the drilling process for further recycling or disposal [11].

The analysis of drilling waste amount showed that when drilling one gas-condensate well to the depth of 3000 m, about 355 m^3 of drilling sludge, 371 m^3 of worked out drilling mud, 728 m^3 of drilling wastewater are formed on average [12].

According to the way of occurance, wastewater formed during the exploration and setting in of oil and gas deposits can be divided into: ballast; drilling; used for cooling; oil and hydrogen mixture; layer; production and rain; household; fecal [13].

DWW is an aggregate-resistant colloid-dispersed system stabilized by chemicals used for drilling mud processing. As for its composition, it contains various mineral and organic matter represented by clay, weighting agents (barite, hematite), oil products, chemicals of various nature, soluble salts, including residues of drilling mud and other compounds [14].

Drilling wastewater is highly versatile and can accumulate contaminants. Therefore, it should be considered as a real environmental threat to the hydro and lithosphere.

Drilling sludge includes 60-80% of rocks; it is mostly silvered mixture of clay, sandstone, argillites, limestone, siltstones, sand. In addition, the composition of the drilling sludge includes organic matter (8% of CMC, starch, lime, etc.), water soluble salts (up to 6%), weighing agents, clay. Therefore, unauthorized dumping of drilling sludge into the environment without special measures to dispose it is inadmissible.

In general, chemical composition of drilling mud is following: 50-60% of SiO_2; 10-18% of Al_2O_3; 3-4% of CaO. The rest is organic matter. The humidity of the drilling mud is 40-45%, the density is 1450-1600 kg/m^3.

The granulometric composition of drilling mud is determined by the type of a drill, its diameter; mechanical properties of the rock; drilling mode; the properties of the drilling mud and effectiveness of its cleaning.

The fractions of sand and clay, the content of which in drilling mud reaches up to 30%, are characterized by the following particle sizes: r=0,05-1,0 mm (35-45%), r<0,05 mm (35-50%).

The composition and properties of oil and gas well drilling waste depends on the mineralogical composition of the drilled rock and the worked out drilling mud. For instance, the approximate mineralogical composition of the drilled rock in the Donets'k-Dnipro basin area on the territory of Kharkiv region includes, in percentage: sand - 11%; limestone - 14%; argilite - 18%; aleurolite - 13%; clay - 19%; sandstone - 25%.

The composition of worked out drilling mud is determined by the specific type of drilling mud used for well drilling (on water or carbohydrate basis, clayey or polymer ones).

For preventing drilling waste penetration into the drilling site and the migration of toxic substances to natural objects, an engineering system for its organized collection, storage and disposal is provided; it is a construction of sludge barns. All drilling waste is dumped into sludge barns, or sludge collectors, in case it is impossible to recycle, dispose, or remove some waste to special polygons immediately. Unfortunately, it can have negative impact on the environment and the health of people living nearby the oil and gas producing regions [15].

Sludge barns are one of the main sources of the environment pollution. When constructing sludge barns, trees, shrubs are cut down, ground cover is destroyed, land exploitation is carried out.

It was researched [16], that there are some changes in the acidity and mineralization of groundwater near the sludge collectors. In addition, nearby the sludge barns, an increase in the concentration of chlorides, heavy metals and oil products in soil and groundwater can be observed.

Sources of the environment pollution are conditionally divided into temporary and permanent. Sludge barns, in which liquid waste is leaked and filtrated, are referred to permanent sources of pollution. Sludge barns used for collecting oil and gas well drilling waste, are constructed with a calculated volume of waste up to 500-800 m^3 per well. The joint storage of all drilling waste does not allow it to be recycled simultaniously, and because of the drawbacks in barn constructions and the specific needs for soil condition, there is no reliable protection of the environment.

Before exploiting the barn, its walls and bottom are insulated with a film coating of waterproof materials: materials based on bitumen, polyethylene film, roofing materials such as ruberoid, etc. The laying of this material must be carried out following strict requirements of construction rules and regulations. The absence of waterproofing coating in the barn causes soil, reservoir and groundwater pollution [17]. When using saline drilling mud, the MAC increase of Cl^- and Na^+ in samples of barns and water sedimentation tanks can occur, which leads to salinization of soils and a significant increase in the total mineralization of groundwater.

When drilling oil and gas wells, a significant man-made load on atmosphere, hydro, and lithosphere objects appears to be and as a result it impacts on the amount of generated drilling waste, in which gas condensate is more than 1 000 m^3 per one well, including 170-355 m^3 of DS, 230-371 m^3 of worked out drilling mud (WDM), 600-728 m^3 of drilling wastewater (DWW).

The main reasons for the deterioration of the environment while exploiting the oil and gas deposits are the following:

– frequent cases of open emission of oil, gas and formation water while opening the productive formation of wells;

- constant pollution of reservoirs and deep formation water with liquid hydrocarbons, highly mineralized water and harmful salts;

- highly polluted atmosphere while exploiting gas deposits and gas storage facilities.

2.1 Impact of drilling waste on the lithosphere

In case worked out drilling mud (WDM), drilling wastewater or drilled rock containing toxic salt components, as well as oil and oil products, fall into the soil, all properties of soil can deteriorate sharply and as a result the yield of certain crops grown in these areas decreases.

The composition of drilling wastewater varies depending on the chemicals included in the drilling mud and drilled rock (Table 2).

Table 2

Characteristics of drilling mud

Indicator	Unit of measurement	Amount
pH	–	7-10
Density	g/cm^3	1,0-1,2
Mechanical impurities	mg/l	180-13000
Oil products	mg/l	10-5300
Dry residue	mg/l	2880-12030
COD	mg O_2/l	100-9300
BOD	mg O_2/l	7-520
Total mineralization	mg/l	1300-22600

The impact of drilling wastewater on the soil and flora mainly comes down to the pollution with oil products and chemicals used to prepare the drilling mud. After contaminating soil with oil products, the air mode and water properties of the soil are violated. At the same time there are changes in microorganisms living in the soil: the number of macroorganisms and bacteria that assimilate nitrogen compounds is reduced. There is a suppression of redox enzymatic processes that, as a result, reduces biological activity and fertility of soils. As a rule, drilling waste has an alkaline reaction, followed by the occurance of easily dissolved humates that are easily washed away from the surface of soils, causing reduction of the total humus content [12].

In the areas polluted with drilling sludge, containing oil products, vegetation dies almost completely.

Drilling wastewater, the main polluting element of which is worked out drilling mud, penetrating into the soil, destroys the soil structure, changes the soil mode and nutrition of plants, as well as its physical and chemical properties. If the concentration of these dangerous pollutants is insignificant, the soil can self-purify and recover. With the increase in pollutant content, more than the maximum acceptible concentration, it threatens all living organisms.

Soil contaminated with hazardous waste drilling is a source of danger for humans, since oil products that are part of drilling waste due to migration ability through food chains occurs in agricultural products, leading to the risk of carcinogenesis.

2.2 Impact of drilling waste on the atmosphere

When drilling oil and gas wells, there is a large amount of pollutants of different toxicity falling into the environment.

Changes in the WBD composition are caused by the technology of drilling and technological parameters (temperature, pressure) of the process, opening the horizon with various chemical fluids (gas, oil and underground water), different mineralogical composition of drilled rock.

When storing drilling sludge, worked out drilling mud and drilling wastewater, and further processing or recycling of drilling waste in sludge barns, evaporation of light fractions of oil products (hydrocarbons) from the mirror of the barn occurs, that negatively affects the atmosphere, especially during snow melting [18].

The amount of light hydrocarbons, that evaporate from the sludge barns and pollute the atmosphere, can range from 0.5 to 2.5 tons per year.

2.3 Impact of drilling waste on the hydrosphere

Non-normative (non-project) arrangement of a sludge barn (absence of earthworks, drainage trenches, violation or lack of waterproofing in the barn) is the main reason for negative impact of drilling waste on underground water and reservoirs. In addition, negative impact is also possible if the drilling mud or drilling wastewater located outside the sludge barn, join atmospheric fallout, as well as during the flooding of the rig territory in the period of intense snow melting.

Atmospheric fallout and snow melting cause the transition of drilling waste dissolved salts to aqueous solutions with the migration of these substances into the aquifers.

In case of improper control over the barn filling and untimely cleansing, flows of the liquid waste phase through the upper boundary of the barn are quite possible.

Also, the penetration of oil, drilling wastewater and worked out drilling mud into underground freshwater horizons is possible in case breaches in the conductor of the operating column occur or due to flow through the low-quality cement stone behind the column.

Contamination of underground water and reservoirs with oil products and chemicals causes suppression of normal organic life, changes in the composition of biocenoses, fish burial and spawning loss.

Under the influence of drilling waste on the water environment, the intensity of photosynthesis and the degree of survival among phytoplankton is reduced.

Components of drilling waste can become hazardous to the environment. It is determined as balance violation in inanimate and living systems of the environment (increased concentration of chemicals, negative effects in the system condition, etc.), reducing the level of safety for living organisms and humans in the environment.

Therefore, the placement and further recycling of drilling waste in sludge barns or at the drilling site can cause significant damage to the environment. Thus, recycling of solid (drilling sludge) and liquid (drilling wastewater and worked out drilling mud) drilling waste that have negative impact on the environment is an important task to be solved [19].

3 Analysis of methods for drilling waste cleaning and recycling

Drilling waste recycling can include recycling, extraction, deactivation and burial of drilling waste.

Types of impact on drilling waste are conditionally divided into physical, chemical, biological and combined. On temporary ground, waste recycling takes place during drilling, right after drilling, several years after drilling and during transportation.

The final materials of waste recycling include construction, meliorative and reclamation final products.

In order to increase the ecological safety of the environment during drilling, at least 3 storage barns for collecting and storing waste with an average total volume of 2500 m^3 and, in addition, an emergency barn for the products of setting in and testing a well with a volume of 200 m^3 (per one well) are constructed. The depth of the barns is 2.5–3 m. The first barn is used to collect worked out drilling mud and drilling sludge; the second one is for collecting and storing drilling wastewater; the third is to collect purified (clarified) water [20].

There is an open and closed system of handling drilling waste.

The open system is unacceptable, while using it, there is an enormous negative impact of pollutants on the environment. The closed system is more efficient to handle the drilling waste:

The closed system of handling drilling waste makes it possible to:

- minimize the amount of drilling waste;
- recycle and process drilling waste;
- carry out the disposal of only safe materials related to the environment.

Solid waste recycling, i.e. drilling mud, is the implementation of technological operations associated with changing the chemical, physical or biological properties of waste. It is done in order to further environmentally safe storage and disposal.

The main methods of drilling sludge recycling are:

- thermal (burning, drying);
- solidification
- physico-chemical methods of drilling waste recycling
- chemical (extraction, solidification using organic and inorganic reagents);

– physical (gravitaty sediment, separation in a centrifuge, separation by filtration, freezing)

– biochemical or biological (biotermal, microbiological decomposition and contaminated soil reclamation).

Types of influence on liquid waste are conditianally divided into: mechanical, physical, chemical, biological, combined [21, 22].

Mechanical methods of purification allow to catch only large fractions of polluting WWD on vibrating screens, which is only the first stage of purification with the further refinement by other more effective methods.

Coagulants are used to accelerate the sedimentation of suspended particles of disperse systems, as well as to intensify the sedimentation of these particles, flocculants.

As a coagulant, aluminum sulfate $Al_2\ (SO_4)_3$ is used, and it is efficient to use polyacrylamide (PAA) as a flocculant. Coagulants lead to disruption of disperse system stability and aggregation of fine fractions into flakes. The main function of polyacrylamide is to help increase the size of the flakes when coagulated [23].

Coagulation plays an important role in water purification processes for the removal of suspended colloid particles, which may add unpleasant taste, color and feculence to drilling wastewater.

Coagulation is the particles adhesion process of the colloid system to their collisions in the process of thermal (Brownian) motion, mixing or direct movement in the external force field. Primary particles in such clusters are connected by the forces of intermolecular interaction directly or through the layer of the surrounding (dispersive) medium. Coagulation is accompanied by progressive aggregation of particles (increasing in size and mass of aggregates) and by decreasing their number in the volume of the dispersion medium, the liquid.

Influenced by coagulants, extremely small dispersed particles are combined in large masses, which later can be removed when separating the solid and liquid phases.

Flocculation is a kind of coagulation, in which small particles, suspended in liquid, form fluffy clusters, i.e. floccultes. Flocculation in liquid disperse systems occurs under the influence of specially added substances - flocculants.

In accordance with the Stokes law, frozen and colloid particles are settled down for a rather long time; therefore the intensification of the deposition process is a necessary measure to reduce the time of purification of drilling wastewater.

Water treatment by coagulation is carried out by adding mineral salts with hydrolyzed cations, anodic dissolution of metals, or just by changing pH of the medium, if treated water (drilling wastewater) already contains in sufficient amounts cations, able to form hydrolyzable poorly soluble compounds.

The most common flocculants are polyacrylamide (PAA); copolymers of acrylamide, acrylonitrile and acrylates; sodium salts of polyacrylic and polymethacrylic acids, etc.

Colloid particles, that are part of the drilling wastewater, are conditionally divided into three types: mineral, organic and biological. Mineral colloids include sedimentary rocks, colloid clays, hydroxides and metal salts. Organic ones include humic and sulfinic acids, which are formed by decomposition of plant and animal mains, as well as dyes, surface active substances, etc. Biological colloids are microorganisms, they can be both pathogens and non-pathogens.

A number of interactions between negatively charged colloid particles and positively charged ones takes place during coagulation.

The colloid suspension is destabilized under the influence of two mechanisms, these are the neutralization of charge and direct chemical binding.

Neutralization of the charge occurs when a positively charged coagulant neutralizes the negative charge situated around the colloid particle. When the charge around each particle is neutralized, they gradually approach, reducing their effective radius. Finally, they become unstable and can collide with each other. When colliding, particles join each other, forming large masses and flakes.

In practice, while purifying drilling wastewater, aluminum salts, iron salts or their mixtures in various proportions are usually used as coagulants. Sometimes, magnesium, zinc and titanium salts can also be used.

The most common coagulants used nowadays include aluminum sulfate, aluminum hydroxychloride, aluminum hydroxychloride sulfate, sulfa-iron-containing reagent, etc.

The effectiveness of coagulants is affected by a large number of factors. The water coagulation technology should take into account the composition and properties of wastewater contaminants, the dose and composition of the coagulant, the temperature and pH of the water, the conditions for the introduction and mixing of the reactants. The decisive factor for maximizing the efficiency of using coagulants in cleaning drilling wastewater is the creation of conditions for their hydrolysis in the right direction by changing the concentration of coagulant in the disperse system, the pH value and the ionic composition of the dispersion medium. The optimal pH values, when using aluminum sulfate as coagulant, is achieved in the range of pH values of the medium from 5 to 7,5, and sodium aluminate from 9.3 to 9.8; when using iron chloride in the range of values from 3,5 to from 6, 5 or 8 to 11; when using iron sulfate from 9 to 10,5.

The common disadvantage of all known coagulants is the inability to regenerate and return the product. Also, the disadvantages of the method include the fact that during the change in the chemical composition of the WWD, process of the particles sedimentation can become unregulated [24].

3.1 Thermal method of drilling sludge processing

This method is quite common, it is usually implemented in open barns; furnaces of various designs (rotary drum kilns, bubbling fireboxes, etc.). The method also includes drying in dryers of different designs; pyrolysis; thermal desorption; electric fire processing; thermolysis; heat treatment.

When burning drilling sludge in a rotary drum kiln, the solid phase is mixed with the loam (30-60% of weight and 40-70% of weight, respectively) and granulated. The liquid phase is used repeatedly to prepare the drilling mud. The disadvantage of this method is high cost.

Pyrolysis is the process of decompositing organic compounds under the influence of high temperatures with absence or lack of oxygen with the formation of harmful by-products like pyrogas and pyrolysis resin, solid phase and heat of waste gases for futher recycling.

Thermal desorption of drilling sludge is the thermal heating of waste with subsequent condensation and capture of the hydrocarbon phase. This method costs a lot because of high energy consumption and low economic efficiency.

Electric fire burning of drilling sludge is characterized by setting almost ideal conditions for environmentally friendly burning of any toxic waste.

In heat treatment of drilling sludge, it is completely disposed at a temperature of 800-850 C due to the chemical conversion of compounds.

The drilling sludge can be practically recycled forming final products: curbtone, cinder blocks, paving slabs, coupling mixture and granular filler for concrete [16].

The high-temperature treatment of the drilling sludge passes two stages:

- preparatory;
- high-speed burning at a temperature of 950 - 1200 °C.

The disadvantage of high-temperature burning is that it needs special equipment and expensive energy resources [17].

In the process of thermolysis drilling sludge forms the following substance:

- water (40% of weight);
- solid carbon residue (21% of weight);
- hydrocarbon distillate (30% of weight);
- hydrocarbon gas (9% of weight) [18].

The thermal method of drilling sludge processing is all-purpose, drilling sludge does not require preliminary preparation (cleaning from garbage, stones, oil products), and the volume of the processed product is ten times less than the initial volume of drilling sludge. But when burning, a large number of dangerous and harmful gases are released in the atmosphere. In order to prevent this negative effect, it is obligatory to conduct emission clearance. This requires additional material, financial and energy resources. The economic efficiency of thermal methods is reduced by the need of drying drilling sludge with high humidity [20].

3.2 Solidification of drilling sludge

Solidification involves processes that encapsulate the contaminated material with the formation of solid material, and limit the migration of the pollutant by reducing the surface area that is alkalined and / or by applying a low permeability material on the contaminated material. Solidification is carried out by means of mechanical processes, which mix material and one or more reagents. Solidification keeps the contaminated material in granules or monolithic matrix.

Solidification technology allows obtaining a durable material on the basis of neutralized waste. The process of neutralizing the sludge is carried out by mixing with sorbent and cement in certain proportions. After that, the organic substances present in the sludge are bound by the introduced sorbents. Cations of heavy metals contained in the sludge are converted into heavy insoluble hydroxides. Solidification of neutralized waste, as a result of hydration processes introduced into the cement system, leads to even stronger binding of neutralized toxic compounds and prevents their further dissolution in case of various environmental factors influence [21]. This product can be used in construction industry.

Advantages of solidification method in drilling sludge processing are:

- it improves the structural property of the soil, waste and sludge (e.g., strength) to facilitate land reusage;
- it can be used for cleaning on or outside the area;
- processing endpoint can be achieved within a relatively short period;
- it can be used in dry or wet conditions, reducing problems of water removal and waste control;
- simple, available equipment and materials are used;
- it does not require transportation of waste from the facility;
- economically effective;
- inert filler, obtained as a result of solid phase drilling waste processing, is used for the reclamation of soil set for temporary sludge collectors;
- no fee for waste placement in case of such treatment with drilling waste.

3.3 Biochemical (biological) methods of drilling waste recycling

Biological substances (bacteria, cultures of fungi, plants) are used. This method is based on the ability of microorganisms to process hydrocarbons. In this case, biochemical reactions occur, accompanied by spliting, mineralization and partial gumification of the contaminated soil layer.

Disadvantages of the biochemical (biological) method are the following:

- long process, requiring large funds for the purchase of biological products;
- the use is limited by the selective action of bacteria;

- bacteria, as a rule, are highly sensitive to the composition of the drilling mud and changes in environmental factors (temperature, humidity, pH, etc.), which prevents the desired result.

A well-known method for processing drilling mud additionally involves purifying it with a corsotry of non-pathogenic oil-oxidactive elements: *Rhodococcus erythropolis*, *Bacillus subtilis*, *Fusarium sp.*, taken in the ratio 1:1:1.

Biological method is optimal in combination with other methods of DW recycling. The degree of DW purification is increased up to 91% after the previous extraction of oil products from sludge by the xylene and treatment with selected consortium of necessary microorganisms.

The success of biological oil purification depends on the ability to establish and maintain conditions facilitating the increase of oil biodegradation level in the contaminated area.

Recycling of the bottom layer of sludge barns can be carried out by the method of biodestruction in field conditions.

Furthermore, the composting of oil waste is carried out together with the overpopulated block of cattle (15 kg/m^3), razor (straw – 45 kg/m^3) and addition of calcium salts ($CaCO_3$ – 5 kg/m^3).

Soil, contaminated with hydrocarbons, causes large damage to the natural environment, as the accumulation of pollutants in animals and plant tissues can cause death or mutation.

Thus, the biological methods of DW processing are used mainly at one of the stages of complex DW handling, which contain oil products. Since the content of oil products in the DS is relatively small, this method is not justified from the technical, ecological and economic plan [3, 20].

3.4 Physical methods for drilling waste recycling

This method is based on changing the physical properties of DW under the influence of various power factors.

Physical methods of DW processing are divided into [25]: gravity sediment, separation in centrifuge, separation by filtering, freezing.

The most commonly used apparatus for separation and further waste processing are centrifuges, filters, hydrocyclones and separators.

Sludge filters, or settlers, are used for dewatering such drilling waste as oil sludge. The advantage of gravity sediment is unnecessity of large capital for operating costs, and the disadvantages include the long-term process of settling and the low effectiveness of oil residues and other impurities separation. The separation of drilling mud in the centrifuge occurs in the decanter. The principle of its action is based on the actions of centrifugal forces. In a decanter, oil sludge in a mixture of heated fresh oil is fed into three-phase decanters, where the separation into three phases occurs: hydrocarbon, water and mechanical impurities. The isolated hydrocarbons are ginen for recycling, water is given for purification, mechanical impurities that are enriched in hydrocarbons and containing water, are recycled as new waste, the amount of which is much less than the amount of the primary sludge, but still significant. The advantages of this kind of DS recycling include the ability to reduce the amount of waste, as well as reuse of water that is separated from oil products. The disadvantages include special equipment, such as hydrocyclones, separators, and centrifuges.

The method of filtering through the press only separates water portion of the waste from heavy impurities; this process is characterized by a rather low throughput. In case of such filtration, the problems of the filtered material recycling and the separation of water remain unresolved. This method does not solve the problem of the complete recycling of oil waste [26].

The influence of freezing and thawing on the dewatering of the sludge emulsion, its structure, number and respiratory activity of the sludge microflora, toxicological characteristics of the sludge liquid phase are determined. It has been found that freezing and thawing causes sludge structure destabilization, followed by quick dewatering centrifugation. For a 20-minute centrifugation it separates from the sludge up to 28% of water, whereas after freezing and thawing it accounts more than 39%. Thus, freezing and thawing destabilize the sludge structure and facilitate increasing the efficiency of its dewatering under the modeling conditions of centrifugation. This method is more suitable for mixtures consisting of synthetic organic substances.

Vibrating screens are used to clean DW from sludge (liquid phase from solid). Using the method of V.N. Ponomarev and Yu.N. Shtonda separation into phase components of the emulsion layer is carried out by the method of water-organic system demulsification on the basis of different intensification effect of mass transfer processes under phase inversion conditions.

3.5 Chemical methods of waste recycling

The chemical method of DW recycling on the basis of reagent encapsulation is an effective technology for recycling waste. When it is used, the physical and mechanical transformations of DW into neutral for the environment material are carried out. Each particle of this material is covered with a hydrophobic shell of calcium carbonate, which is formed by slaking lime with water and carbon dioxide:

$$CaO+H_2O=Ca(OH)_2,\ \Delta H=-65{,}26\ kJ/mole$$

$$Ca(OH)_2+CO_2=CaCO_3+H_2O$$

When slaking lime, there is an exothermic reaction (the allocation of thermal energy), the evaporation of excess moisture and the death of microorganisms is carried out. Granules, after maturation for 24 hours, have high strength, and the rate of of hazardous substances release in the environment is reduced to hundreds of times.

The ratio of DW and quicklime is, according to experiments, from 1:0,8 to 1:1,2.

Also, for the implementation of the DW reagent processing method, a neutralizing composition (NC) is used as a mixture of calcium oxide, sorbent and a modifier.

The method of DW inertia is binding of toxic substances to sorbents, thus obtaining solidification material on the account of mixing activator. The mixture for solidification is used in the following proportion: 40-80% of cement; 20-60% of natural silica gel; 20% of non-liquid glass. The result of solidification is the material for leveling the terrain, the construction of insulating screens and the construction of roads [27].

Composite building material, containing DW with density 1.38-1.8 kg/dm^3, cement 4-12 wt. (astringent); dehumidifier and mineral filler, can also be obtained.

Conclusion:

The least costly means that have been used previously, such as recycling of drilling waste by discharging wastewater to the relief, pumping wastewater, crushed pulp of DW and DS into the reservoir, dumping the DS without any treatment in the barns, are unacceptable and do not follow modern requirements to the environment protection.

It is expedient to use drilling sludge as additives for production of building materials, considering the composition of the sludge and raw materials.

Drilling wastewater has to be cleaned with coagulants and flocculants.

It is also efficient to add worked out drilling mud as filler for production of polyethylene, also using polypropylene waste compositions.

The development and improvement of methods for drilling sludge, drilling wastewater and worked out drilling mud processing are important for further research direction.

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